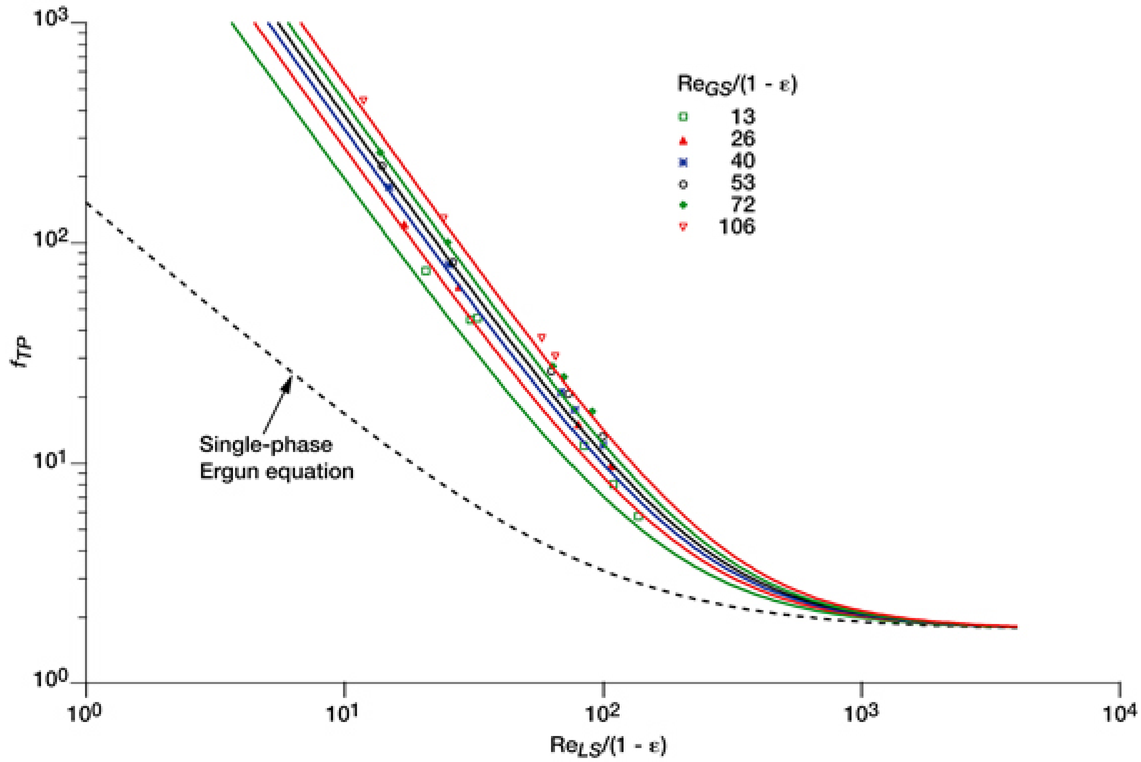
Operation of Packed-Bed Reactors Studied in Microgravity

The operation of a packed bed reactor (PBR) involves gas and liquid flowing simultaneously through a fixed-bed of solid particles. Depending on the application, the particles can be various shapes and sizes but are generally designed to force the two fluid phases through a tortuous route of narrow channels connecting the interstitial space. The PBR is the most common type of reactor in industry because it provides for intimate contact and high rates of transport between the phases needed to sustain chemical or biological reactions. The packing may also serve as either a catalyst or as a support for growing biological material. Furthermore, this type of reactor is relatively compact and requires minimal power to operate. This makes it an excellent candidate for unit operations in support of long-duration human space activities.

A NASA Research Announcement award to the University of Houston, Notre Dame University, and NASA Glenn Research Center is currently supporting research for fundamental studies of the PBR in a microgravity environment. Through this award, a series of experiments have flown on NASA's reduced-gravity aircraft. As a result of the experimental effort, models for pressure drop and flow regime transitions have been developed and recently published (ref. 1).

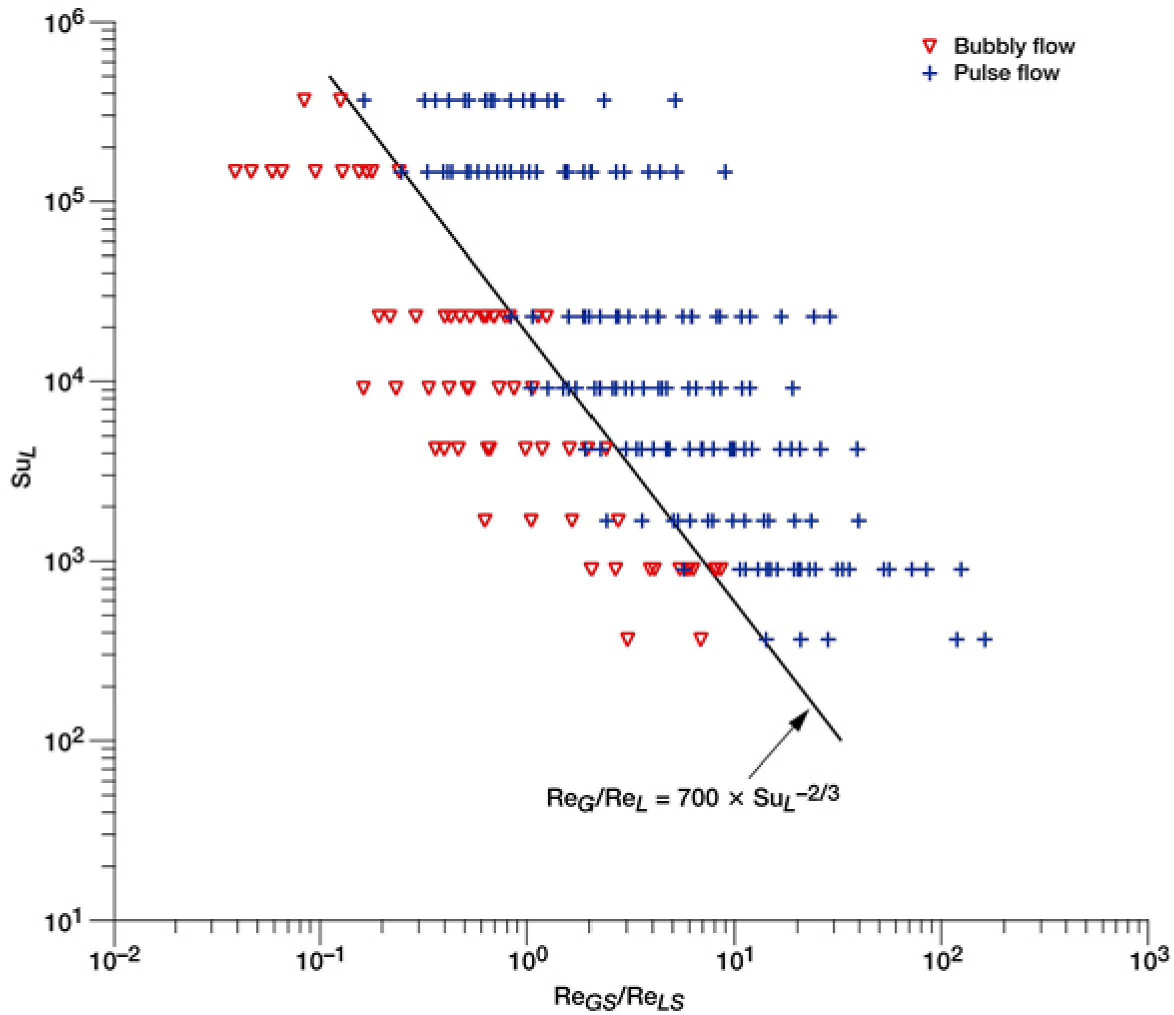


Pressure-drop model for microgravity operation for Suratman number Su = 146,000. Re_{GS} and Re_{LS}, Reynolds numbers for superficial gas and liquid flows, respectively; f_{TP}, modified two-phase friction factor.

Long description. In this figure, a series of plots are shown for a number of different gas Reynolds numbers for a Suratman number equal to 146,000. The plot is a log-log plot of the two-phase friction losses versus the liquid Reynolds number divided by one minus the void fraction. These are the same coordinates used to plot the single-phase Ergun equation, which is also shown as a reference. The new curves show a much higher total pressure drop for two-phase flow asymptotically approaching the single-phase equation at higher liquid Reynolds numbers. Experimental data are shown as points along each curve.

The preceding graph shows an example of the new pressure drop model for reduced gravity. The model is based on the well-known Ergun equation which is used to describe single-phase flow through porous media. The new model extends this equation by including a term to account for pressure losses associated with the interaction between the gas and liquid phases. This term could not be validated in a normal-gravity environment because of the masking effects of gravity.

A flow regime transition map was also developed for microgravity and is shown in the following graph. Through dimensional analysis, it was shown that the transition from bubbly flow to pulse flow (flow with alternating gas and liquid slugs) is a function of the gas and liquid Reynolds numbers and the Suratman number *Su*. This number arises in the analysis of capillary effects in small-diameter tubes and jets and is the ratio of the liquid Reynolds number to the capillary number. The transition occurs when the ratio of the Reynolds numbers for the superficial gas and liquid flows ($\mathrm{Re}_{GS}/\mathrm{Re}_{LS}$) = $700 \times Su^{-2/3}$.



Transition map between bubbly and pulse flow for the microgravity environment. Su = Re/Ca; Suratman number of liquid, Su_L.

Long description. In this figure, a straight line is drawn in a log-log plot of the Suratman number versus the ratio of gas to liquid Reynolds numbers. The equation for the line is given in the main text. Data for pulse and bubbly flow in microgravity are shown on the plot.

Future work is planned to study the effects of gravity on other parameters that affect the design and operation of the PBR. For example, the quasi-steady pulse characteristics are a strong function of gravity and greatly influence the mixing and mass transfer of the reactor. The goal of this research is to fully understand the operational characteristics of the PBR in microgravity. Then engineers may be able to take advantage of this environment to develop a reactor for space applications with an operational efficiency equal to or greater than the present levels found in terrestrial systems.

Reference

1. Motil, B.J.; Balakotaiah, V.; and Kamotani, Y.: Gas-Liquid Two-Phase Flows Through Packed Beds in Microgravity. AIChE J., vol. 49, no. 3, 2003, pp. 557-565.

Find out more about this research at
http://microgravity.grc.nasa.gov/6712/research.htm

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